Baseline and Multimodal UAV GCS Interface Design

Progress Report

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Abstract

To improve operational effectiveness for the Canadian Forces (CF), the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project is acquiring a medium altitude, long-endurance (MALE) uninhabited aerial vehicle (UAV). In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating the human factors issues of UAV ground control stations (GCS) interfaces for UAVs and exploring possible solutions using multimodal displays. This progress report provides an update project from March of 2011 to December of 2011 of this Baseline and Multimodal UAV GCS Interface Design. The report discusses the pilot testing of the baseline condition of the experiment. In addition, the progress of the multimodal display design is provided. The implementation of the multimodal display design to the experiment is also addressed.

Executive summary

Baseline and Multimodal UAV GCS Interface Design: Progress Report

[Wayne Giang, Yeti Li, Catherine Burns]; DRDC Toronto TR [enter number only: 9999-999]; July 2013.

Background: Uninhabited aerial vehicles (UAVs) are remotely controlled aircraft used for a variety of civilian and military applications including command, control, communications, computers, intelligence, surveillance and reconnaissance (C4ISR). To improve C4ISR capability, the Canadian Forces (CF) is acquiring a medium-altitude, long-endurance (MALE) UAV under the Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project. In support of the JUSTAS project, Defence Research and Development Canada (DRDC) – Toronto is investigating the human factors issues of UAV ground control stations (GCS) interfaces for UAVs and exploring possible solutions using multimodal displays. This project, the Baseline and Multimodal UAV GCS Interface Design, is ongoing as of December of 2011.

Results: As of December of 2011, the pilot testing for the baseline condition of the study was completed. Several issues of the experimental environment were identified and resolved. The baseline condition of the GCS simulator was stable and ready to run participants. Automated methods for aggregating and analyzing the data were being created to accelerate the process of data collection and preliminary data analysis.

The multimodal display for the experiment was being developed. The report described the finalized auditory and tactile displays and their implementation into the multimodal condition of the experiment. The auditory sonification of engine RPM and auditory warnings were designed and introduced to the experiment. The tactile display to present attitude upset of the UAV was being developed. This additional experiment was planned and designed to compare the sequential and equalizer attitude upset presentation. The effectiveness of various tactile displays will be evaluated to examine how well they are able to communicate levels of tactile upset.

Significance: The report discusses the completion of the pilot testing for the baseline condition of the experiment. The significance of the multimodal display design and the implementation of the multimodal display design to the experiment are also addressed.

Future plans: In early 2012, the future plans of the project were to complete running of the baseline GCS condition for participants and finalize the designs of the multimodal displays, including running of the tactile experiment.

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1 Introduction

An uninhabited aerial vehicle (UAV) is an aircraft system without an onboard pilot or crew. The UAV is controlled from a ground control station (GCS). Today's UAVs are highly automated and to some extent, autonomous. UAVs can be directed to follow a pre-programmed mission; they can fly to designated waypoints, fly specific patterns, correct for course deviations and hold above a particular coordinate or target. Some UAVs can perform automated take-off and landing (e.g., the CU-170 Heron used by the Canadian Forces during the war in Afghanistan). UAV developers argue that automation and autonomy provide several benefits: (a) increased flight safety; (b) simplified operations; (c) lower operating costs; and (d) reduced operator workload (Attar, 2005). However, these benefits are not always realized. Along with the benefits of automation, some disadvantages occur such as loss of situation awareness (Endsley and Kiris, 1995; Endsley, 1996), loss of supervisory control (Parasuraman, Molloy, Mouloua, & Hilburn, 1996; Sheridan, 1987), information deprivation that occurs from remote operations (Manning, Rash, LeDuc, Noback, & McKeon, 2004), and high workload levels for operators (Lee, 2008; Woods, 1996). These issues point to the need for improved interfaces to help these operators remain in the loop and maintain situation awareness during the remote monitoring tasks typical of UAV monitoring.

The work described in this report is in support of the Canadian Forces (CF) Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System (JUSTAS) project. The JUSTAS project entails the acquisition of a long endurance UAV. This work is directed towards understanding the human monitoring challenges with UAVs similar to the UAVs that could be acquired through the JUSTAS project. Further, this project will explore the use of multimodal interfaces for UAV control leading to new design criteria for UAV ground control stations, or improved requirements for future acquisitions.

This work builds on the work of Giang et al., 2010 which reviewed the current research on multimodal displays and ecological displays for UAV control. This report is a mid-project progress report detailing the work that has occurred in order to prepare for a large scale study of two GCS designs. One of the GCS designs will be a visual interface (called the “baseline condition”), essentially simulating a typical UAV visual interface. The other design will be a multimodal interface where tactile and auditory information will be added to the interface to see if this new information can improve operator performance and situation awareness.

A number of goals have been accomplished over the last few months, since the submission of our last contract report in March 2011, to support the design and testing of a multimodal UAV GCS simulator. This report will start with a brief review of the past achievements in our last contract report in March, 2011. This report will also outline the progress in two activities: the pilot testing of the baseline condition of the experiment and the design of the multimodal GCS interface. The goal of this report is to provide a short summary of the results achieved in these two activities.

2 Pilot testing of the Baseline condition of the Experiment

In April of 2011, pilot testing of the baseline condition of the experiment was started. This pilot testing was performed to examine the suitability of the experimental guidelines and to evaluate the stability of the experimental platform. The experiment was conducted with two participant groups. The naive participant group had no pilot experience and the expert participant group had recently acquired at least ten flying hours. Over the last 8 months, 10 naïve participants in the GCS baseline condition were successfully tested. However, a number of complications occurred during this pilot testing that delayed the running of the experiment until the beginning of 2012. In late October 2011, the experiment room was closed for renovation. The experiment equipment was moved to an alternate room. This resulted in a small delay in running the baseline condition. In the middle of November 2011, we encountered a technical problem on the eye tracking system, and the troubleshooting and verification lasted until late December 2011. The pilot test showed that overall our experimental guidelines and procedures were effective. However, a number of modifications to the procedure were necessary. Our situational awareness questionnaire which was implemented during the experimental session had a number of questions that were confusing to our pilot participants. The situational awareness questions were clarified based on suggestions from the pilot participants. Additionally, a practice scenario in which the UAV lands safely was added to the training phase. Therefore, two practice scenarios are now provided to the participants during the training phase, one where the participant is required to abort the landing and one where the UAV can land safely. The additional practice scenario was added to remove the bias of experiencing only an abort scenario during the training phase. A new visual indicator of engine revolutions per minute (RPM) was added on the visual interface of the UAV landing display, and the participant was required to monitor this indicator during the scenario. An additional sheet of instructions was also provided after the training video to provide participants with information regarding the RPM indicator

Aside from stability of the GCS experimental platform, there were two other challenges encountered during the pilot study. One challenge was that participants with glasses could not be reliably calibrated using the eye tracking system. The experimental protocol was changed to recruit only those who had normal vision or who had corrected to normal vision using contact lenses. Another challenge was in scheduling of participants. Each participant was required to come in for three 2 hour sessions in the course of one working week. This made scheduling difficult with three time-slots per day, and only 15 possible slots each week. The experimental procedure was changed to allow for three sessions within 7 days instead of one working week to make scheduling easier, but schedule changes and cancellations late in the week can still resulted in scheduling conflicts.

During the pilot test, several problems with the experimental platform were also encountered that led to the loss of data during some of the pilot sessions. After running the 10 participants, almost 30% of the data collected was affected by some aspect of the experimental platform crashing; in fact, each of our 10 participants had at least one scenario which resulted in some loss of data. The errors encountered involved a number of components in the GCS simulator including the experimenter console, the x-plane simulation, the secondary task and situation awareness questions, and the eye tracking system. In the subsequent months, the team debugged and fixed many of the errors. As of December, 2011, all of the problems that were encountered during the pilot testing were resolved and testing of the GCS baseline condition was ready to begin.

The results of the pilot test indicated that participants were able to respond to most of the simulation events. Participants were instructed to press the button labelled "Operator Concern" if they detected any critical events (e.g., wind shear, turbulence, or RPM warnings). For the 10 pilot subjects, 300 events occurred. Out of 300 of such events, only 2 (0.667%) events did not receive any responses and 19 (6.33%) events had responses that occurred longer than 10 seconds from the onset of the event. The average response time for the participants pressing the operator concern button after the start of an event was 4.5 seconds. In the secondary task, a trial was presented every 2 seconds. The participant was required to respond during this window. A successful response on the true target was regarded as a hit, while a response on a false target was judged as a false alarm. In this simulation of a wind shear monitoring task, participants had an average hit percentage of 78.84% and a false alarm percentage of 7.12%.

Most of this preliminary data analysis was done manually by calculating and extracting values from the experiment log files, which was a very time consuming process. The simulation produces a number of different log files and an automated process for aggregating the log files into a single log file was created to facilitate the analysis process. Automated scripts for calculating many of the descriptive statistics for data analysis (such as average reaction times, hit rates and false alarm rates) are currently being created.

In summary, after pilot testing the baseline condition of the study, a number of issues were identified and resolved. Currently, the baseline condition of the GCS simulator is stable and ready for the running of participants. Automated methods for aggregating and analyzing the data are being created and will facilitate the examination of data once data is collected. The remaining challenges over the coming months will be the efficient scheduling of participants, and reviewing the log files for any errors or bugs.

3 Multimodal GCS Interface

In the last contract report (Giang et al., 2011), a number of ideas were proposed for the auditory and tactile interfaces for the multimodal GCS interface. This section of the report will describe the finalized auditory and tactile displays and their implementation in the multimodal condition of the experiment.

3.1 Auditory Sonification of Engine RPM

An auditory sonification was used to represent the current state of engine RPM. Two types of events are important to monitor with regard to engine RPM, low engine RPM and high engine RPM. When the UAV's engine RPM becomes too low, it is possible that the engine will no longer provide enough thrust and the UAV will stall; thus troubleshooting a low engine RPM event should be a high priority for the GCS operator. In contrast, when the UAV's engine RPM becomes too high, it may cause the engine to burnout, which is also an important event to monitor for, but not as high of a priority as a low engine RPM event. Normally, during steady flight, the UAV's engine RPM should remain at a steady value. Deviation from this normal value may indicate potential problems with the UAV.

An auditory sonification was created to display the engine RPM value to the operator using the auditory modality. A sample clip of an UAV engine was analyzed using a fast Fourier transform to determine its constituent frequencies and their amplitudes. A sonification was created to reproduce the frequency spectrum of the UAV engine, but with the ability to adjust the fundamental frequency and its harmonics (pitch). The pitch of the engine RPM sonification was mapped to the current status of the engine RPM. As the engine RPM increases, the fundamental frequency and the harmonics of the sonification also increase to reflect the status of the engine in real time. Similarly, as the engine RPM falls, the pitch of the sonification also decreases. The base fundamental frequency, used for normal engine RPM conditions, is 107.2 Hz, and this represented an engine RPM of 2350. Currently, the transformation between engine RPM value and frequency is:

$$freq = \frac{RPM}{21.5}$$

In the baseline condition of the experiment, yellow and red visual warnings appear when the engine RPM rises or falls past certain thresholds. The cautionary yellow warning appears when the engine RPM value increases or decreases to a level that the operator should be concerned about. The emergency red warning appears when the engine RPM increases or decreases to a level that requires immediate attention.

We specified the thresholds for the low engine RPM warnings to be 2150 (for a yellow warning) and 2050 (for a red warning). For the high engine RPM, the thresholds are 2550 (for a yellow warning) and 2750 (for a red warning). For experimental purposes, we also constrained the engine RPM to have low and high limits (1900 for the low engine RPM and 2825 for the high engine RPM warnings). These limits were put in place such that a low engine RPM event would be in the red warning region for a longer duration than the yellow warning, while the high engine RPM event would be in the yellow region for longer than the red; this reinforces the urgency of the low engine RPM events. These mappings are summarized in Table 1.

Table 1. RPM level mapping to visual and auditory indications

RPM Level	RPM Reading	Visual Warning	Auditory Alarm
Low Low	1900 to 2050	Red (Low RPM)	Most urgent alarm
High Low	2050 to 2150	Yellow (Low RPM)	No alarm
Normal	2150 to 2550	None	No alarm
Low High	2550 to 2750	Yellow (High RPM)	No alarm
High High	2750 to 2825	Red (High RPM)	Second most urgent alarm

Another important aspect of the RPM sonification was the conveying of auditory urgency (Edworthy, Loxley, & Dennis, 1991). For this experiment, it was important that the sonification conveyed that low engine RPM events are more urgent relative compared to high engine RPM events. To incorporate the communication of urgency into the sonification, we added warning sounds over the original engine RPM sonification (which we refer to as overlay alarms).

Auditory alarms were created by selecting two auditory alarms from Experiment 8 of Edworthy et al. (1991). In this experiment, Edworthy et al. examined the perceived urgency of a number of different auditory characteristics in different alarms. Two alarms of different urgencies (the most urgent alarm and the 6th most urgent alarm) were selected as overlay alarms. The most urgent alarm was used for low engine RPM events. When the engine RPM dropped into the red warning region (below 2050 RPM), the sonification produced both the engine RPM and the most urgent auditory alarm. The auditory alarm continued until the engine RPM decreased below 2050 RPM. Similarly, the second auditory alarm (which was less urgent) was heard with the sonification when the engine RPM went above 2750 RPM, which was the threshold for the high engine RPM red warning. The signal to noise ratios for the auditory alarms and the base sonification have not yet been finalized.

In summary, in addition to the visual alerts, operators will be alerted to changes in engine RPM using two auditory methods. First, the pitch of the sonification will indicate the current status of the engine RPM. Higher pitch represents higher engine RPM and lower pitch represents lower engine RPM. Changes in pitch should provide the operator with a cue that the engine RPM is deviating from normal. Second, when the engine RPM reaches the thresholds for red warnings, overlay alarms will be played to indicate to the operator that the engine RPM has reached a level that requires immediate attention. In a previous study, Edworthy showed that there is a relationship between warning sound parameters and perceived urgency. A more urgent sound will be used for low engine RPM events because of the higher priority of such events when compared to high engine RPM events (Edworthy et al., 1991).

3.2 Tactile Attitude Upset Display

A tactile display was chosen to represent changes in the UAV's attitude. During flight, a UAV may encounter turbulence or wind shear that will change the attitude of the vehicle. Attitude upset refers to any changes to the aircrafts pitch, roll, and yaw from an intended position. Attitude upsets are important to communicate to the UAV operator because they may require immediate action from the operator. For example, during a landing, a severe attitude upset may require that an operator abort the landing of the UAV, while even light wind shear and turbulence may warrant operator concern. However, unlike a human piloted aircraft, the UAV operator does not have any tactile or vestibular feedback associated with the UAV's attitude. Thus, a tactile vest will be used to communicate real-time attitude upset information to the operator. The display will present an aggregated value representing the magnitude of the attitude upset.

To design the tactile display, we first examined the effect of varying levels of wind shear and turbulence on the attitude of the UAV. Logs from the GCS simulator provided roll, pitch and yaw information from the UAV as it encountered wind shear and turbulence. A set of graphs were generated from these logs to demonstrate the roll, pitch and yaw information in different levels of wind shear and turbulence. Four magnitudes of the events, which are used in experiment scenarios were examined and indicated in Figure 1.

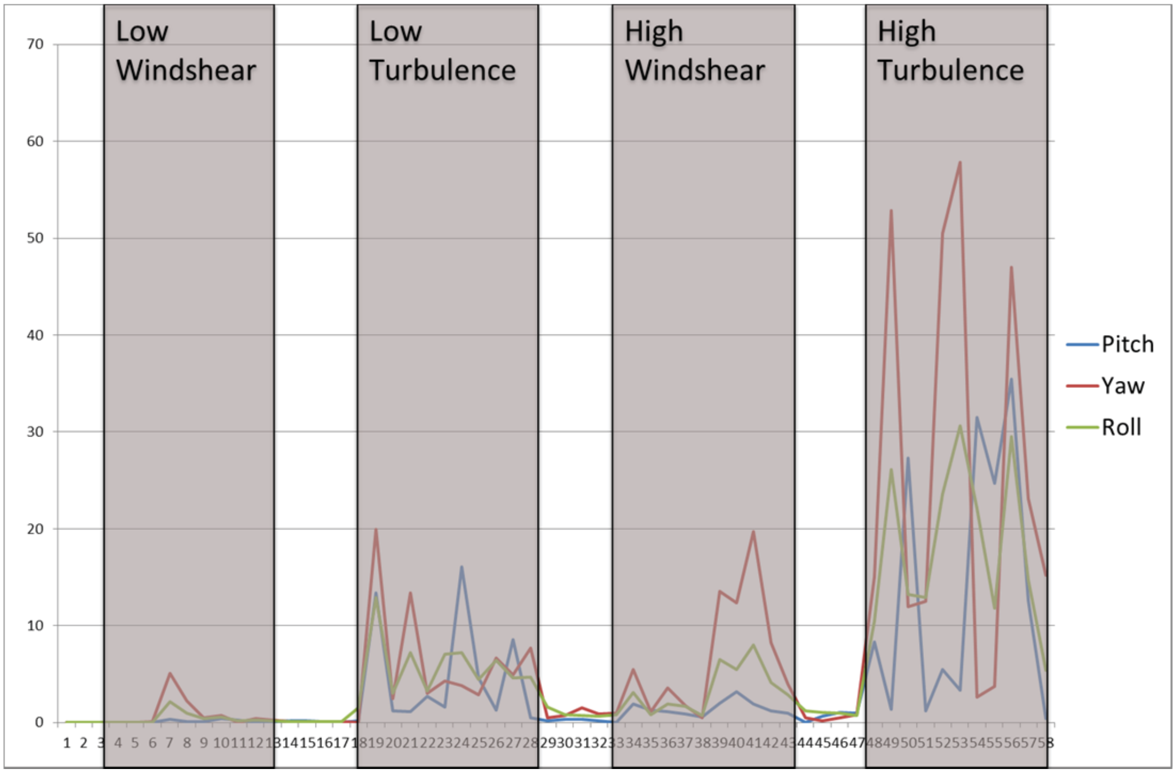

Figure 1. Graph of Varying Levels of Wind shear and Turbulence

From these logs, it was decided that the magnitude of the aggregate attitude upset value should be based on the change in the rate of roll and pitch, and exclude measures of yaw. Yaw was not used because changes in yaw were much more likely to be associated with the pre-planned path changes during the recovery of the UAV than attitude upset from wind shear or turbulence. The tactile display will use the following calculation to determine the magnitude of the attitude change:

$$attitude\ upset = \frac{(|Roll\ rate| + |Pitch\ rate|)}{2}$$

The attitude upset information will be displayed using an array of tactors, which are small vibro-tactile motors which provide tactile stimulation to a single location on the skin, located on the participant's back. A sample configuration can be seen in Figure 2. The display shows four levels of attitude upset: a null zone where no tactors are activated and three levels of activation.

Figure 2. Arrangement of Tactors.

The attitude upset thresholds for each level are shown in Table 2.

Table 2. Attitude Upset to Level Mapping

Attitude Upset	**Level**
0-1.5	Null Zone (No Activation)
1.5-3	Level 1
3-16	Level 2
16+	Level 3

The configuration of the tactors and the tactile patterns used are still to be determined based on the results of a separate experiment that will be run in the coming months. Two tactile patterns and two layouts are being evaluated for use, and only one pattern and one layout will be selected for use in the multimodal GCS experiment. The first tactile pattern is referred to as the "sequence" activation pattern (Giang et al, 2011). In this method of activation, the vertical distance of the activated tactor from the body's transverse plane presents the magnitude of the deviation. For example when the magnitude of the UAV's deviation changes from Level 1 to Level 2, the Level 1 tactor is deactivated and the Level 2 tactor is activated. The second tactile pattern is what we have called the "equalizer" activation pattern (Giang et al, 2011). With this type of activation the number of activated tactors represents the magnitude of the deviation. With the equalizer method, the tactor located on the lower level is not deactivated when the track deviation increases from one level to another. The two layouts are either a single 3 tactor column or two columns of 3 tactors.

In summary, the tactile attitude upset display is used to show the UAV operator when the UAV is experiencing an attitude upset due to wind shear or turbulence. An aggregate value for attitude upset is calculated using an average of the absolute value of rate of roll change and rate of pitch change. This aggregate attitude upset value will then be measured in real time during a UAV flight. If this value exceeds our pre-determined attitude thresholds, the tactors on a tactile vest worn by the participant will activate, displaying the information to the participant. Further testing of the tactile attitude upset display is still required to determine whether the level thresholds are appropriate and the type of pattern and layout to be used.

3.3 Tactile Experiment

The effectiveness of various tactile displays will be evaluated to examine how well they are able to communicate levels of tactile upset. This additional experiment was planned and designed to compare the sequential and equalizer attitude upset presentation.

Four display types will be tested which vary along two dimensions: the number of columns (1 vs. 2) and the activation type (equalizer vs. sequential). All four designs display the magnitude of the attitude deviation using a "bar-graph" like tactile display along the upper back of the participant. The tactile display is comprised of tactors placed within a vest worn by the participant. The tactors will be arranged into columns of four tactors, with either 1 or 2 columns present on the back depending on the type of display used. Four tactors are used for each column to ensure that each tactor is easily localizable. The spatial acuity of the back is approximately 3 cm, and each tactor will be placed 3 cm away from either other (edge-to-edge).

3.3.1 Design

Two tasks will be used, one to examine the discriminability of the displays and one to gauge the perceived urgency. After completion of both tasks, a questionnaire about the annoyance level of each of the designs will be provided to the participants.

3.3.2 Discriminability Task

The discriminability task will examine how well participants are able to detect different levels of attitude deviation. The discriminability task will be divided into two parts. The first part examines how well participants are able to detect and localize the activation of a single level. This will also serve as a baseline for the second part which will focus on how well participants are able to discriminate between different levels after a tactile pattern is played.

Participants will first be familiarized with the four tactile displays. Participants will experience the two different activation types (sequential vs. equalizer) and the two layout types (one vs. two columns). Participants will then experience examples of each of the four levels for each of the displays.

After this familiarization phase, participants will begin the single level activation section. In this part, participants will be presented with a single level of activation for one of the displays. Participants will be asked to respond the level of activation presented using a keyboard, and will indicate the level of activation by pressing the appropriate number key (1, 2, 3, or 4). Participants will be asked to respond as quickly as possible. Response times and accuracy will be recorded. Each condition will be replicated 10 times and the order of presentation will be randomized. This section should take approximately 11 minutes to complete (160 trials x 4 sec per trial).

The second part will examine participant's ability to discriminate between different levels of activation after they are presented a tactile pattern. This part will test whether a tactile pattern improves or hinders discrimination, and also test the effects of habituation and adaptation. Two types of tactile patterns will be used and are shown in Figure 3.

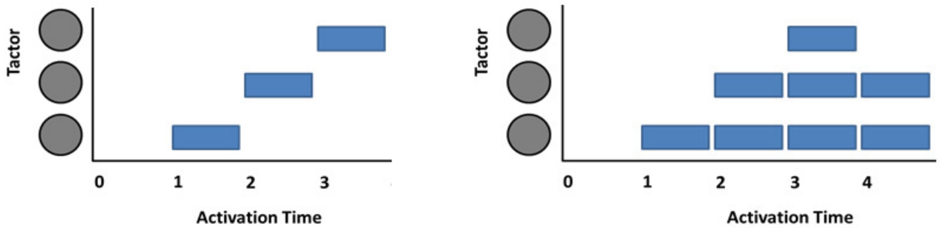

Figure 3. Left - "Up" activation sequence for the "sequential" display. Right - "Up-Down" pattern of activation for the "equalizer" display.

In the first pattern, tactors activate one at a time to the target level in sequence, with an inter-tactor duration set between each level of activation; this type of pattern is named the “up pattern”. The second pattern is very similar to the first, but instead of stopping at the target level, the pattern will first go to the next level before returning to the target level; this type of pattern is named the “up-down” pattern. The participant’s task is to indicate the level of activation after the pattern as stabilized and they will be asked to do this as quickly and as accurately as possible. Participants will indicate the final level of activation using a keyboard by pressing the appropriate number key (0, 1, 2, 3, or 4). The independent variables are the type of pattern, the final level of activation, the inter-tactor duration (3 levels which still need to be determined), and the display type (4 types). The dependent variables will be response time and accuracy. Each condition will be replicated 5 times and the order of presentation will be randomized. This task is estimated to take approximately 80 minutes

3.3.3 Urgency Task

The goal of this task will be to determine the perceived urgency of the four display types, the different locations of tactors (which are represented by different levels of activation), and different inter-tactor durations. The urgency task will also be divided into two parts: the first with single tactor activations, and the second with tactile patterns.

In the first part, participants will be presented with a single level of activation of one of the displays for 5 seconds. Participants will then be asked to report the perceived urgency of the stimuli on a scale between 1 and 100 using a scale adopted from Arrabito, Mondor, and Kent (2004) and shown in Figure 4. Each condition will be repeated 5 times and the order of presentation will be randomized. This part is estimated to take approximately 15 minutes to complete (80 trials x ~10 sec per trial).

Figure 4. Urgency Reporting Screen.

In the second part, participants will be presented tactile patterns and will be asked to report the perceived urgency. Because the equalizer design requires a starting point, two types of equalizer designs will be tested. For the buttom-up design, the activation of Level 1 starts at the bottom tactor, the activation of Level 2 occurs at the middle tactor and finally the activation of Level 4 occurs at the top tactor, and vice versus, the top-down design starts at the top tactor. The goal of these two designs is to examine if perceived urgency can be affected by the starting/ending point of the tactor activation.

The independent variables will be the final level of activation, the inter-tactor duration (3 levels which still need to be determined), and the display type (6 types (one column + two column, bottom-up equalizer, top-down equalizer, sequential). The dependent variable is the ratings of perceived urgency. Each condition will be replicated 5 times and the order of presentation will be randomized. This section should take approximately (4(level)*3(ITD)*6(display type) = 72 conditions, 360 trials * ~ 10sec per trial = 60 minutes).

4 Implementation of Multimodal Displays in the GCS Simulation

Two multimodal displays were integrated into the code of the GCS simulation. Stub code for interfacing with the Tucker Davis Technologies (TDT) System 3 and the Engineering Acoustics Inc. (EAI) Tactor Unit for the multimodal displays was added to the GCS simulation code (Tucker Davis, 2011).

4.1 Auditory Sonification

The TDT was used as the sound generator integrated into the GCS Simulation. The service supplier also provided a visualized auditory circuit development environment named the System 3. The team successfully built an auditory circuit (shown in Figure 5) under the System 3 development environment to create the sonification as well as overlay alarms. Overlay alarms were developed using .wav files varying in high urgency sounds provided to us by Dr. Judy Edworthy. These sounds were used in her research (Edworthy et al., 1991). We established six links in the circuit. The links (shown in Table 3) are used to turn alarms on and off and to adjust the TDT System 3 volumes in the GCS code. The volumes include control over the signal to noise ratio of the overlay sounds and the engine RPM sonification volume.

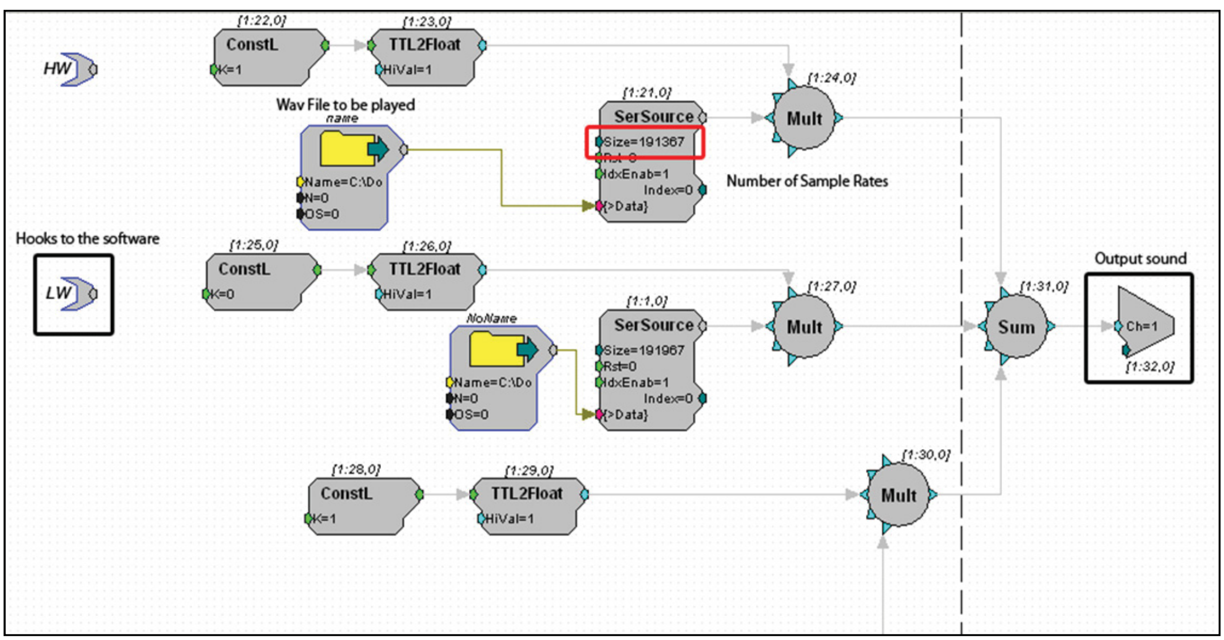

Figure 5. Tucker-Davies Technologies Auditory Circuit

Table 3. Auditory Links

Links	Level
LW	Turn the Low Engine RPM alarm on or off
HW	Turn the High Engine RPM alarm on or off
LWVol	Increase or decrease Low Engine RPM volume
HWVol	Increase or decrease High Engine RPM volume
Freq	Set the fundamental frequency of the engine RPM sonification
FreqVol	Increase or decrease engine RPM sonification

4.2 Tactile Information

The EAI Tactor Unit came equipped with a visualized development environment, the TAction Writer. Tactile patterns were incorporated and played in the GCS simulation by function calls in the GCS code. An attitude monitor was embedded into the code. The GCS simulation monitored the magnitude of attitude upset, and played specific tactile patterns on the Tactor Unit. The tactors presented the tactile signals and the participant received the stimuli through the vest.

5 Summary

In conclusion, the project made significant progress from March of 2011 to December of 2011. A number of stability issues with the experimental platform have been resolved that are important for both the baseline and multimodal conditions. As of December 2011, the baseline condition is being run. In addition, the design of the stimuli for the multimodal GCS condition was finalized and the preliminary implementation of multimodal output from the simulator was working well. The auditory circuit changes the pitch of the engine RPM sonification correspondingly with the values in the engine RPM indicator. The tactile display responds to attitude upsets at pre-determined upset thresholds as designed. In early 2012, the goals of the project were to: 1) complete running of the baseline GCS condition for both naïve participants and participants with flying experience; 2) finalize the designs of the multimodal displays, including running of the tactile display experiment; 3) begin piloting of the multimodal GCS condition. The team's progress up to this point has made it possible to accomplish these goals in the near future.

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List of symbols/abbreviations/acronyms/initialisms

CF	Canadian Forces
DRDC	Defence Research & Development Canada
GCS	Ground Control Station
JUSTAS	Joint Unmanned Aerial Vehicle Surveillance Target Acquisition System
RPM	Revolutions per minute
RPvdsEX	Real-Time Processor Visual Design Studio
R&D	Research & Development
UAV	Uninhabited Aerial Vehicle